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INFLUENCE OF AGGREGATE’S TREATMENT ON PROPERTIES OF RECYCLED AGGREGATE CONCRETE

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ABSTRACT

The comparative result of the experiments of fresh and hardened concrete with different replacement ratios of natural aggregate with recycled coarse aggregate and recycled fine aggregate is presented in this paper. Four types of concrete mixtures were tested: concrete made Completely with natural aggregate (NAC) as a control concrete and three others types of concrete made with recycled fine aggregate and treated recycled coarse aggregate. In this study replacement of Natural aggregate is restricted up to 30% of coarse recycled aggregate. Moreover fine aggregates replaced in 50% and 100% to Fine recycle aggregates. There are three types of treatment under consideration for recycled aggregate (1) Abrasion of Recycled Aggregate (RA) (2) Cement slurry coating of RA (3) Chemical immersion of RA.

The results indicate that concrete produced with higher percentage of fine RA shows less workability in comparison to control concrete. It was found that strength of RCA concrete have equivalent or higher performance to concrete made with natural aggregates, for corresponding 28-day design strengths. Abrasion treatment to Recycled aggregate gives better result in all among treatments. The replacement ratio of coarse RA and fine RA is not affected in satisfactory performance recycled aggregate concrete (RAC) results.

Key words: recycled fine aggregate, recycled coarse aggregate, Abrasion treatment, chemical treatment.

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1. INTRODUCTION

Due to development process the demand for new buildings increase that is the reason for Development in the concrete industry. After useful life of structure this concrete generates the waste material largely known as C&D waste. The management of waste create major environmental effect on the agricultural land and hinders natural resource preservation. There has found the scarcity of dumping grounds which is made worse by the occupation and rising value of urban areas, high social costs of waste management and public sanitation. [1]. the depletion of natural sand and natural aggregate encourage to use alternative raw material which deposits close to large urban centers. Waste materials produced from either demolished concrete Structures or from industrial precasting of concrete members, are the potential sources for Recycled Concrete Aggregates (RCAs), and can possibly be employed for producing new cement-based composites, such as ecological concretes or mortars [2] Recycled concrete Aggregate (RCA) is a material; where in natural aggregates (65–70%) are coated by cement mortar (30–35%) and can be produced from the crushing of concrete into smaller pieces [3]. This attached mortar has higher porosity and lower density than the natural crushed stone, which is known to be the major area for concerned for effective use in concrete. Earlier works confirmed that RA had inferior properties like low density, more water absorption and reduction in quality and durability due to the mortar that remains attached to NA [4] the attached mortar has an influence on the water absorption rate of the RA, since it has high porosity. Therefore, to maintain a uniform quality during production a method to offset the water absorption of the RA is usually employed. The high absorption capacity of RA means that more water is needed than for conventional concrete. Other investigations point out that the physical and mechanical properties of RAC strongly depend on the quality like nature, size and grading of the recycled aggregates [5]. The heterogeneity influences the characteristics of recycled aggregates and these aggregate properties have a negative influence on recycled aggregate concrete quality such as reduction of the compressive strength, tensile strength due to the increased concrete porosity and a weak aggregate–matrix interfacial bond [6, 7].

Compressive strength of RAC depends on many parameters like replacement level of RA, w/c ratio, moisture condition of RA etc [8,9]. Various researchers reported, the reduction in compressive strength is up to 30% as compared to natural aggregate concrete at 100% replacement. [10, 11, 12]. For the purpose of reduce RCA water absorption and to improve RAC properties, researchers have investigated various methods. Li et al. [13] studied the effect of pre-coating RCA with different pozzolanic powders such as fly ash, slag, and silica fume before mixing RCA with the cement paste. As a result, the compressive strength of RCA concrete is further enhanced. in Another method to modify RCA surface with coating, Kou and Poon [14] impregnated RCA with polyvinyl alcohol (PVA) solution, found considerable reduction in water absorption and improve crushing value (10%) of RCA.Gonzalez and Martinez [15] Limbachiya et al.[16], Ishtiyeg Gull [17] have studied the fresh properties of RAC and conclude that RA remarkably lowers the workability of RAC. It may be due to the higher water absorption of RA when compared with natural aggregate (NA). Moreover these researchers have proved that the desired workability can be achieved by using appropriate mineral and chemical admixtures. Yong and Teo [17] have suggested the use of recycled aggregate in saturated surface dry condition to enhance the workability. To achieve desired workability use of pre wet recycled aggregate was suggested by Fong and Jaime [18] while researching the literature pertaining to Treatment techniques for RA, it was found that there is very limited study on use of treated coarse and fine RA. Revathi Purushothaman et al [19] studied various method to improve the properties of RA and concluded that it can be improved by suitable chemical or mechanical treatments. Moreover

the Sallehan Ismail [20] studied the pozzolanic reaction is attributed to increase the strength of the concrete.

This paper reports the effect of the various treatments apply to RA and evaluate the physical and mechanical properties of the coarse RCA. This paper also highlights the effectiveness of the use of this treated RA with fine recycled aggregate in fresh and hardened concrete.

2. MATERIALS AND METHODS

This part reports the details of the materials used in the experimental tests and the procedures carried out for processing the coarse recycled aggregate and how the recycled concrete aggregates (RCAs) were obtained.

Experiments were carried out in three stages. In first stage there was preliminary investigation of materials like Ordinary Portland Cement (OPC) of 53 Grade, Aggregate and sand. The standard tests have been performed to characterize the cement and other materials, results are tabulated. In second stage experiments of various treatment of recycled aggregate were conducted and in third stage Concrete prepared after treatment to RA.

2.1. Materials

(1) Cement: In this experimental program the Ordinary Portland cement was used. This was Conforming to IS 8112-1989 (IS 1989) [21], the Specific gravity of cement was found 3.15.

(2) Natural sand*:* Locally available river Sand was used as per Indian Standard 383-1970 [22]. The Physical properties of river sand determined as per IS 2386 (Part III)-1963 (IS 1963) [23] Sand was confirming to Zone-I. The values of Specific gravity, and fineness modulus of sand was 2.65, 3.54 respectively.

(3) Natural Aggregate: In this experiments Locally available crushed coarse aggregate passing through 20mm and retain on 10 mm is sieve; conforming to Indian Standard 383-1970 [23] was used. Specific gravity of coarse aggregate was 2.86. Table 1 shows other Physical properties of Natural aggregates. The mechanical properties of NA and RA were determined in accordance with IS 2386-1963 (IS 1963).

(4) Recycled Aggregate: The laboratory tested and crushed concrete specimen waste available in large quantity to nearby the institute. This laboratory tested cubes were for part of the construction work of bridge near vicinity. This is used as the source of RA. These concrete crushed cubes were further crushed manually and subsequently crushed with a lab model jaw crusher and sieved. The aggregate passing in 20mm sieve and retained on 10 mm sieve was used as RA.

(5) Recycled fine sand: Recycled fine sand produced as waste part of abrasion treatment given to Recycled coarse aggregate and use of jaw crusher for obtaining coarse Recycled aggregate. During this procedure some residue left which is finer material. This finer material used as Recycled fine sand and its particle size was less than 4.75 mm. The physical and mechanical properties of coarse aggregates is presented in Table-1

Table 1 Properties of NA and RA obtained after different treatment methods

Properties	Natural Aggregate	Recycled aggregate (Without Treatment)	Abrasion treated RA	Cement Slurry coated RA	Chemical soaking RA (HCl)	Chemical soaking RA (H_2SO_4)
Specific Gravity	2.86	2.41	2.48	2.45	2.50	2.49
Water absorption (%)	1.15	9.7	3.92	5.15	6.15	6.23
Impact Value (%)	9.52	16.94	13.23	14.26	15.99	17.12
Crushing Value (%)	24.67	32.95	26.13	28.16	27.13	27.36
Abrasion Value (%)	14.68	24.92	20.46	23.36	25.14	26.47

2.2. Methods to Improve properties of Recycled coarse Aggregate

In order to improve the quality of RA, several techniques have been developed in literature the main objective is to removes the loose mortar particle on the surface. In this experimental study, three treatment techniques are adopted for improving the quality of RA.

2.2.1. Abrasion of RA

The recycled concrete aggregates employed in these experiments were obtained from the tested laboratory cubes from ongoing construction of bridge near to Porbandar polytechnic. This selected sources were processed in the following steps (1) Manual crushing, (2) crushing with laboratory jaw crusher (3) sieving, aiming at transforming the debris of tested cubes in to aggregates of the appropriate size.

For the purpose of reducing the amount of fine materials attached to the surface of recycled aggregates (mainly debris from cement paste and sand, called ''attached mortar''), an abrasion treatment process was performed. In this treatment method coarse recycled aggregate were placed inside Los Angeles abrasion machine. It consists of a hollow steel cylinder, closed at both the ends with an internal diameter of 700 mm and length 500 mm and capable of rotating about its horizontal axis. A removable steel shaft projecting radials 88 mm into cylinder and extending full length (i.e.500 mm) is mounted firmly on the interior of cylinder. The Rotation the machine was kept at a speed of 25 revolutions per minute for 5 minutes without charge inside. Due to rotation of drum, aggregate particle strikes with each other due to this rubbing process attached mortar are removed.

Several trails in terms of Revolution per minute (RPM) of abrasion machine have been taken for optimization of drum rotation duration. Table 2 shows the result of this trail. Criteria adopted for selection of Drum rotation duration was Water absorption Percentage of RA after treatment. Trial results shows that treated product left after revolution of 5 Min absorbs 3.92% water which is minimum among other trails, hence 5 minute duration adopted for the purpose of treatment of RA. One more criteria under the study was percentage remaining of coarse RA particles after treatment. The results of trails shows that after 5 min revolution of drum ,17.4% of total mass of aggregate falls under the less then 10mm size which was not used as coarse RA in the concrete preparation. However remaining 82.6% of aggregate was used as coarse Aggregate in concrete.

Table 2 Details of Drum rotation duration and retention of RA %

Particulars	Drum Rotation duration			
	1 Min.	**2 Min.**	**5 Min.**	**10 Min.**
Percentage of RA (less than 10 mm size) after abrasion treatment	4.5%	11%	17.4%	19.5%

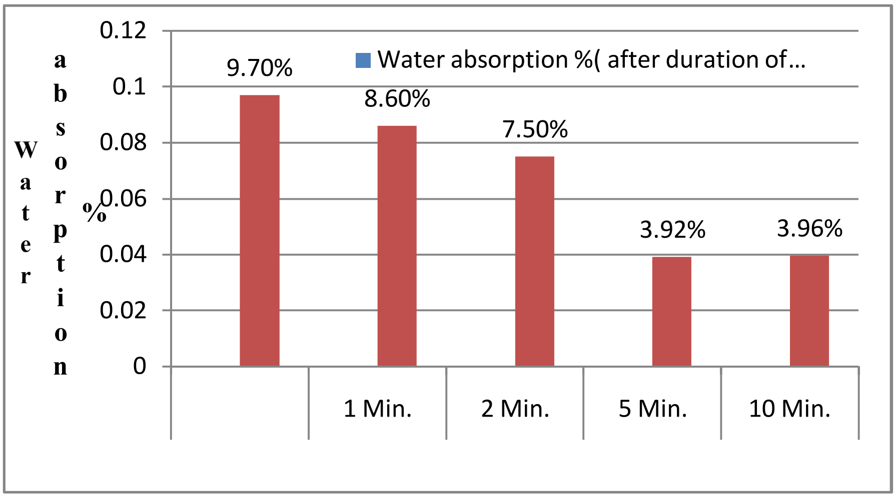

Figure 1 Water absorption % after abrasion of RA

2.2.2. Cement slurry coating of RA

In this treatment method paste was prepared with cement & water. Cement 10% by weight of water was dissolved in water and the mixture was stirred for several minutes to ensure the proper dispersion. Recycled coarse aggregate is soaked in this cement water paste for 24 hours. After immersion, the aggregates were drained, arranged on a tray, and dried in an oven for 24 h at 105 °C. This dry recycled aggregate is used in concrete preparation.

2.2.3. Chemical Immersion of RA

In order to remove the loosely adhered mortar that was attached to the original RA, recycled coarse aggregates were presoaked in an acid for 24 h and then washed with water to remove the acid. There were two types of acid used (1) hydrochloric acid (HCl) (2) and sulfuric acid (H_2SO_4). The acid has concentration of 0.2 mole. This chemical HCl and (H_2SO_4) were added to the RCA sample in two different plastic containers until it covered the RCA surface. After immersion for 24 hours, the aggregates were washed with water, and then coarse RA were placed in an oven and dried for 24 h at 105 °C.

2.3. Concrete Mix Design

Indian standard method [IS 10262 (IS 2009)] applicable for natural aggregate is adopted for The mix design of concrete ,Which is prepared based on constant effective water/cement ratio of 0.57 for all concrete mixtures to achieve targeted mean strength of 27.6 MPa at the 28th day for M20 grade of Concrete. The mix proportion (by weight) was arrived at as 1:1.53:3.28, (cement: fine: coarse) with a cement content of 388 kg per m^3.In this study, 30%, replacement of RA by weight of the total coarse aggregate content was used. In addition to coarse RA replacement fine RA is also replaced with 50 and 100% with natural sand. These batches were distinguished by the different % replacement of coarse RA and fine RA. one batch of mixtures was prepared with untreated RCA, with all natural ingredients and served as control sample for comparison.

2.4. Mixing of Concrete Mixtures

Preparation of all the Concrete mixture batches in this experimental study is as per the IS 10262 method. All the concrete specimens were cast under laboratory conditions. It was removed from mould 24 h after casting, and then fully submerged in water at 27 °C until further testing.

2.5. Testing of Specimen

This study assess the workability and strength parameters like compressive strength, tensile strength and flexural strength of the concrete , the aim to investigate the effect of different proportions of treated and untreated coarse RA and fine aggregate on the fresh and hardened concretes. Slump tests of fresh concrete were performed to determine the concrete workability immediately after mixing. The slump test procedure was conducted in accordance with IS: 1199-1959.The properties of the fresh concrete prepared with treated RCA and fine RA were analyzed and then compared with those of the control concrete samples with untreated RCA.

The total of 14 series of concrete mixes was prepared. In each series of mix 150-mm size cubes used for compressive strength measurement, 150-mm diameter, 300-mm long cylinders were used for splitting tensile strength and for determination of flexural strength 10x10x50 cm size specimen was used for cast in each of the mix series. These test specimens were cured in water under laboratory conditions until the age of testing. The compressive strength and splitting tensile strength of the specimen were determined at 28, days of age.

2.6. Notations of Concrete Mix

NAC stands for control concrete of natural aggregate and natural sand. In this experiment programme it is represented by Mix 'A." While 30% Replacement of Coarse RA (untreated) with Natural aggregate is expressed as Mix"B", similarly various other mix with coarse and fine RA replacement and with given treatment treatment is expressed as C to N, the detail explanation of this mix series is given in Table-3.

Table 3 Details of Concrete Mix series

Sr No	Mix	Series	Percentage Replacement of coarse and fine RA		Remarks
			Coarse RA%	Fine RA%	
1	NAC	A	0	0	Natural Aggregate Concrete
2	RAC	B	30	0	Concrete Without Treatment of RA
3	RAC(AT)	C	30	0	Concrete with Abrasion treatment of RA
4		D	30	50	
5		E	30	100	
6	RAC(CS)	F	30	0	Concrete with Cement Slurry Coated RA
7		G	30	50	
8		H	30	100	
9	RAC(Hcl)	I	30	0	Concrete with Chemical (HCL)Treated(Soaked) RA
10		J	30	50	
11		K	30	100	
12	RAC(H_2SO_4)	L	30	0	Concrete with Chemical (H2SO4)Treated(Soaked) RA
13		M	30	50	
14		N	30	100	

3. RESULTS AND DISCUSSION

3.1. Basic Properties of Aggregates

Water absorption and specific gravity tests are used to determine the basic properties of RA. The properties of the coarse natural aggregate, normal (untreated) RCA, and treated RCA are presented in Table I. In order to identify the mechanical characteristics of the coarse aggregates the Impact value test, abrasion value test and crushing value test was performed.

The specific gravity of RA was found to be 2.41, which is lower than the specific gravity of natural aggregate of 2.86. The water absorption of NA and RA are 1.15 and 9.7%, respectively. The governing factors affecting specific gravity and water absorption of RA are the source of aggregate and the old mortars adhering to it. However, it is observed from Table I that these qualities are improved in RA through treatment techniques. The reason behind this improvement is that this treatment techniques remove the attached mortar adhered to RA efficiently. Comparing the RA after various treatments, the RA properties were found to greatly improve after applying abrasion treatment among rest of techniques.

The impact value, crushing value and Abrasion Value are the common tests, which are prescribed for finding the strength of the aggregate. The impact value is calculated by recording the fractions passing and retained in a 2.36-mm sieve after the material has received 15 blows from a standard weight. This is expressed as a percentage of the total weight. This test is carried out to measure the resistance of a particular aggregate to sudden impact. The lower percentage indicates tougher and stronger aggregates. The results shown in table I indicate that the impact values of NA and RA are 9.52 and 16.94%. The crushing values of NA and RA are 24.67 and 32.95%, respectively. It is clear that, the resistance against crushing, impact and abrasion of RA are relatively lower than NA; this may be due to the porous mortar coating. The impact values and crushing values of abrasion treated RA are improved to the value of 16.94 to 13.23 %(22%) and 32.95 to 26.13 %,(20%) respectively. Looking to the results of other improvement techniques, this abrasion treatment gives better results. Improvement is due to the effect of treatment techniques adopted. Aggregate abrasion value shows Hardness of the aggregate and it is defined as the resistance to wear. It is determined by the Los Angeles abrasion testing machine. The abrasion value of NA and RA is 14.68% and 24.92%, respectively. The effect of treatment is noticeable in improving the hardness of the aggregate, as it reduces the abrasion value of RA from 17%, which shows improvement in abrasion value after treatments, among all the methods for RA improvement, the abrasion treatment shows better results.

3.2. Workability Measurement by Slump Test

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. The apparatus used for doing slump test are Slump cone and Tamping rod.the workability of each batch of Concrete mix are shown in Figure 2.

The slump value of 145 mm was obtained in the NAC and reduces as fine RA used in preparing the concrete. The reason behind this is due to the rough texture, relatively larger surface area of RA and fine RA absorbs more water that increase higher water demand as compared with NAC. Workability of concrete mixes prepared with treated RA is higher than normal RAC and a maximum workability of 145 mm was observed in concrete prepared with abrasion treated RA. The finer particle absorbs more water and produce stiff mix when higher percentage of fine RA is replaced in RAC. In all other types of treatment similar trends observed as fine RA percentage increase the workability reduce ,where fine recycled aggregate not used in that Concrete mix ,abrasion treated RA gives better workability compare to others treatments of RA.

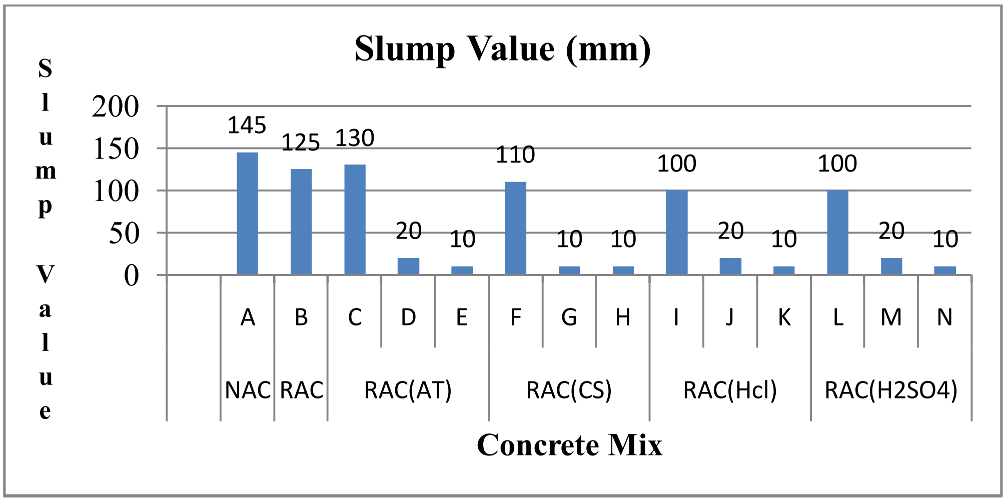

Figure 2 Slump value for various concrete Mix

3.3. Strength Measurement

3.3.1. Compressive Strength

The effectiveness of treatments adopted for recycled aggregates evaluated by conducting several compressive strength tests, flexural strength and tensile strength tests. The compressive strength of concrete specimens made out of the mixtures was determined at an age of 28 days according to IS 516 (1959): Method of Tests for Strength of Concrete.The compressive strength results presented in fig.3 are the average of three measurements. The strength achieved by various RAC, and NAC is graphically represented in Fig. 3. From this figure, it is seen that the 28 days compressive strength of RAC is at par or more then NAC in case of RAC (AT) and RAC (CS). In case of where the chemical treated RA used in concrete, the strength is less than the control concrete. This reduced strength is due to inefficient removal of adhered mortar by chemical treatment. Reasons may be the higher initial free water content in the concrete mixture due to the higher water absorption of RA (Table I).it is clearly observed from the graph that where fine RA 50% and 100 % used gives better strength, this may be due to water absorption of finer particles overall reduces the water cement ratio resulting in higher strength. In all types of treatments of RA, Compressive strength of RAC (AT) gives better strength.

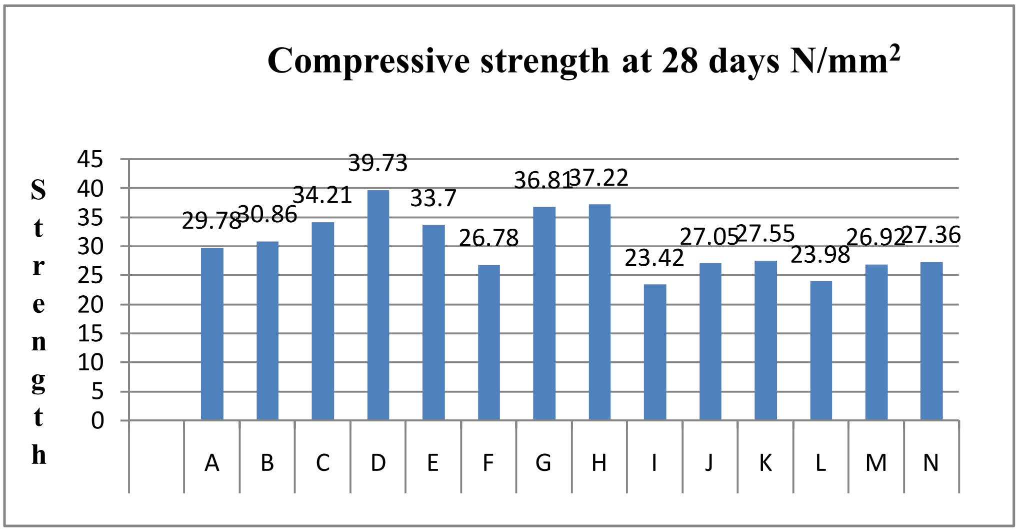

Figure 3 Compressive strength of various concrete Mix

3.3.2. Flexural Strength and Splitting Tensile Strength

The flexural test is usually preferred for quality control of concrete in highway and airport runways, where bending is predominant. Flexural strength testing was conducted according to IS 516 (1959): Method of Tests for Strength of Concrete on samples with dimensions 10x10x50 cm. The beam specimen is simply supported on two rollers of 4.5 cm diameter. The flexural tensile strength is calculated as the ratio of the calculated bending moment and section modulus of the beam specimen. Split tensile strength of concrete was performed as per IS 5816-1959. Cylinders of 150mm diameter and 300mm length were casted. The samples are cured for 28 days. The test is conducted on compression testing machine of capacity 3000 KN. Results from the splitting tensile strength tests on containing treated and untreated RCAs at 28 days of curing is shown in Table-4.

Table 4 Flexural strength and splitting tensile strength at 28 days

Mix	Series	Flexural strength N/mm^2	Splitting tensile strength N/mm^2
NAC	A	5.73	2.29
RAC	B	4.2	1.71
RAC(AT)	C	6.95	2.25
	D	5.26	3.6
	E	5.2	3.72
RAC(CS)	F	4.06	2.14
	G	5.03	3.58
	H	5.03	3.7
RAC(Hcl)	I	3.96	2.05
	J	5.15	2.15
	K	5.2	2.26
RAC(H_2SO_4)	L	4.03	2.14
	M	4.96	2.05
	N	5.15	2.24

4. SUMMARY AND CONCLUSIONS

The experimental investigation was conducted to improve compressive strength of RAC using various treatment methods for recycled coarse aggregate, The experimental results showed that the compressive strength of RAC can be improved significantly, and the strength can reach to 39.73 MPa which is sufficient for structural application

Treatment of aggregates can improve the properties of fresh and hardened RAC. With a abrasion treatment method, the attached residual cement paste on recycled aggregates can be removed and thus the workability of fresh RAC can be improved. The water- cement ratio of mix with fine RA replacement can be lowered and thus the compressive strength of RAC can be enhanced.

Particularly, the following considerations can be remarked.

- Abrasion treatment procedure at the laboratory produce good results in terms of enhancement of properties of recycled aggregates, especially in terms of reduction of the attached mortar content on RCA surfaces and, consequently, on their water absorption capacity.
- In order to improve the property of RA to use in concrete, all three methods are suitable and give at par results in comparison to NAC; however for the simplicity and performance based the abrasion treatment is more suitable method.

- Workability of concrete decreasing with increase of incorporation of fine recycled aggregates, especially when 50% and 100% replacement of fine aggregates. This 100% fine aggregate replacement shows very stiff and hence less workable mix.

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REFERENCES

[1] Pinto TP. Methodology for differentiated management of solid waste from urban construction. PhD thesis on construction engineering, Brazil: Polytechnic School of São Paulo University, São Paulo; 1999 [in Portuguese]

[2] Toledo Filho RD, Koenders EAB, Pepe M, Cordeiro GC, Fairbairn EMR, Martinelli E. Rio 2016 sustainable construction commitments lead to new developments in recycled aggregate concrete. Civil Eng Spec Issue 2013;166(CE6)

[3] D. Kong, T. Lei, J. Zheng, C. Ma, J. Jiang, J. Jiang, Effect and mechanism of surface-coating pozzalanics materials around aggregate on properties and ITZ microstructure of recycled aggregate concrete, Construction and Building Material . 24 (5) (2010) 701–708.

[4] De Juan MS, Gutiérrez PA. Study on the influence of attached mortar content on the properties of recycled concrete aggregate. Construction Building Material 2009;23(2):872–877.

[5] McNeil K, Kang TH-K. Recycled concrete aggregates: a review. International Journal of Concrete Structures and Materials 2013;7(1):61–69.

[6] R. Zaharieva, F.B. Bodin, F. Skoczlas, E. Wirquin, Assessment of the surface permeation properties of recycled aggregate concrete, Cem. Concr. Compos. 25 (2003) 223–232.

[7] G.C. Lee, H.B. Choi, Study on interfacial transition zone properties of recycled aggregate by micro-hardness test, Construction and Building Material. 40 (2013) 455–460.

[8] Ajdukiewicz A, Kliszczewicz A. Influence of recycled aggregates on mechanical properties of HS/HPC. Cement and Concrete Composite 2002; 2:269–79

[9] Poon CS, Shui ZH, Lam L. Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates. Construction and Building material 2004;18:461–8.

[10] Ravindrajah RS, Loo YH, Tam CT. Recycled concrete as fine and coarse aggregates in concrete. Mag Concr Res 1987;39(141):214–20.

[11] Chen HJ, Yen T, Chen KH. Use of building rubbles as recycled aggregates. Cement Concrete Reserch 2003;33:125–132

[12] Tam VWY, Gao XF, Tam CM. Micro structural analysis of recycled aggregate concrete produced from two-stage mixing approach. Cement Concrete Research 2005;35(6):1195–203.

[13] Li J, Xiao H, Zhou Y. Influence of coating recycled aggregate surface with pozzolanic powder on properties of recycled aggregate concrete. Construction Building Material 2009;23(3):1287–91

[14] Kou S-C, Poon C-S. Properties of concrete prepared with PVA- impregnated recycled concrete aggregates. Cement and Concrete Composites 2010; 32(8):649–54.

[15] Gonzalez, B., and Martínez, F. (2008). "Concretes with aggregates from demolition waste and silica fume." Materials and Mechanical Properties. Building Environment., 43(4), 429–437

[16] Limbachiya, M. C., Koulouris, A., Roberts, J. J., and Fried, A. N. (2004). Performance of recycled aggregate, Kingston Univ., Concrete RILEM Publication Sarl, Bagneux, U.K., 127–136

[17] Gull, I. (2011). "Testing of strength of recycled waste concrete and its applicability." Journal of Construction Engineering and Managemen, 10.1061/(ASCE)CO.1943-7862.0000255,

[18] Yong, P. L., and Teo, D. C. L. (2009). "Utilization of recycled aggregate as coarse aggregate in concrete." Journal of Civil Engineering, 1(1), 29–36.

[19] Purushothaman R, Amirthavalli RR, Karan L. Influence of Treatment Methods on the Strength and Performance Characteristics of Recycled Aggregate Concrete. 2000. doi:10.1061/(ASCE)MT.1943-5533.0001128.

[20] Ismail S, Ramli M. Engineering properties of treated recycled concrete aggregate (RCA) for structural applications. Construction and. Building. Material. 2010;44(2013):464-476.

[21] IS: 12269 – 1987 Specifications for 53 – grade ordinary Portland cement

[22] BIS: 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete, New Delhi, India: Bureau of Indian Standards.

[23] IS 2386-3 (1963): Methods of test for aggregates for concrete, Part 3: Specific gravity, density, voids, absorption and bulking

[24] Pinal C. Khergamwala, Dr. Jagbir Singh and Dr. Rajesh Kumar, Experimental Study on Shear Behavior of Reinforced Recycled Aggregate Concrete Beams, International Journal of Civil Engineering and Technology, 7(2), 2016, pp. 128–139.

[25] Ing John K. Makunza, Sustainable Concrete Made From Recycled Aggregates, International Journal of Civil Engineering and Technology, 7(3), 2016, pp. 241–251.